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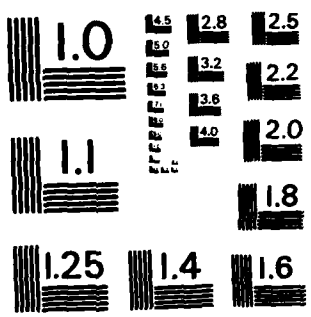

ANNUAL REPORT

FOR THE CONTRACT PERIOD

1 APRIL, 1983 - 31 MARCH, 1984

to

OFFICE OF NAVAL RESEARCH

Principal Investigators:

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for

CONTRACT NUMBER N00014-82-C-0404

THE FLORIDA STATE UNIVERSITY
DEPARTMENT OF OCEANOGRAPHY
TALLAHASSEE, FLORIDA 32306

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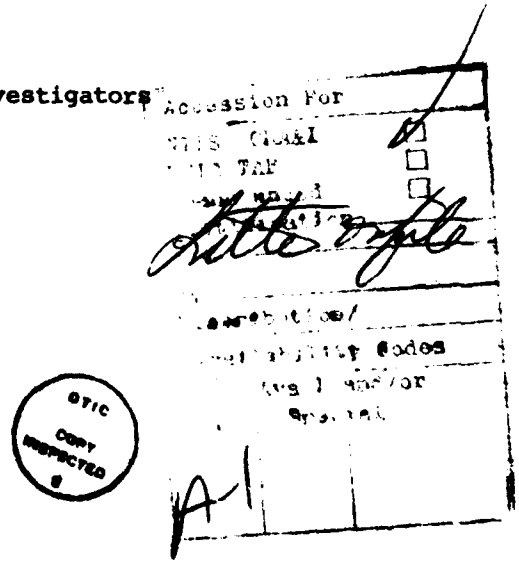
TABLE OF CONTENTS:



A Numerical Study of Currents in the Adjacent Seas of Northeast China

Y. Hsueh

The long-term objective of the project remains that of developing a better understanding of the manner with which mass, momentum, and heat are transferred in coastal seas.

Specifically, the immediate goals of the project are: (1) to unravel the winter-time wind-driven response of the Northeast China Sea basin; (2) to understand the effect of winter-time cooling in setting up density contrasts and associated circulation patterns; and (3) to determine the shape and flow of coastal fronts.

Results to date indicate that the winter-time wind-driven response of the basin is comprised of a sea-level set-up to the south under north wind surges that frequent this region with nearly weekly regularity. Numerical experiments with a linear barotropic model confirm that the set-up along the west coast of Korea is particularly dominating and arises mainly as a consequence of the termination, at the end of the Korean Peninsula, of the generally north-south running coastline that supports a one-sided divergence under the prevailing north wind. As the north wind abates, free, coastally trapped waves (probably a mixture of both barotropic Kelvin and continental shelf waves) appear which carry disturbances around the entire basin perimeter in a counterclockwise sense. Free waves are found chiefly at three frequencies, 0.2, 0.33, and 0.5 cpd. Numerical experiments narrow the frequency selection process to one of nonlinear wave-wave interaction, as the peak frequencies nearly fulfill a resonant criterion for continental shelf waves. The pressure gradient force is found to be important in deep offshore waters and contributes, during the relaxation, to an upwind (northward) flow along the axis of the Yellow Sea embayment. As the forcing is in the form of short-duration pulses, the relaxation response emerges as the primary component of the mean circulation in the Yellow Sea and inner East China Sea where the wind-driven flow dominates. In the outer East China Sea, the mean flow is dominated by the Kuroshio. The superposition of the two components yields long suspected cyclonic gyres in the Yellow Sea and in the East China Sea region southwest of Cheju. The northward mean current in the middle of the Yellow Sea provides an apparent extention to the northward flowing Kuroshio branch and may be a part of the so-called Yellow Sea Warm Current, at least in winter.

The incorporation, into the model, of the (vertically integrated) conservation of heat is also accomplished. The heat equation is nonlinear and allows inputs of latent, sensible, and radiative heat losses. Prelimnary results obtained without surface cooling indicate dominance by advection by the wind-driven flow. Following the initial imposition of a north-south linear temperature distribution (from 25° C along the southern model boundary to 9° C to the northern extreme), a temperature field is achieved in about 20 days that yields 10-day mean distributions bearing qualitatively

resemblance to those published routinely by the Japan Meteorological Agency (JMA). There are only minor changes in the circulation pattern. The cyclonic gyre is preserved in the Yellow Sea, leading possibly to the formation, later in the year, of the core of the Yellow Sea Cold Water.

At the writing, model runs that incorporate surface cooling are being made. Latent and sensible heat fluxes are computed using surface temperatures extracted from the six-hourly weather charts and the 10-day mean sea-surface temperature fields published by the JMA. Radiative heat fluxes are estimated on the basis of JMA-reported cloud covers. Bulk aerodynamic formula are used in the heat flux calculations. Plans are to run the model for, at least, the first 40-day of the 1980-81 winter to explore (a) the mechanism of cold water formation in the Yellow Sea and to chart its movement; (b) the extent of possible sea ice cover in the shallow northern reaches; (c) the heat budget of the entire basin; and (d) the mechanism of the formation and migration of the oceanic fronts in the East China Sea.

Publications

Hsueh, Y., 1983: Circulation in the coastal ocean by G.T. Csanady. Book review. EOS, 64, 933.

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Hsueh, Y., and Richard D. Romea, 1983: Wintertime winds and coastal sea-level fluctuations in the Northeast China Sea. Part I: Observations. J. Phys. Oceanogr.. In press.

Hsueh, Y., Richard D. Romea, and P.W. DeWitt, 1984: Winter-time winds and coastal sea-level fluctuations in the Northeast China Sea. Part II: Numerical model. Submitted to J. Phys. Oceanogr..

Mesoscale Processes in the Ocean

Doron Nof

I. Introduction: During the present contract period, research along two separate avenues is conducted. The first addresses the dynamics of isolated eddies and the other is concerned with flows through channels and straits. In the area of eddy dynamics, the major efforts are associated with the behavior of eddies in the open ocean; the emphasis of the straits studies is on the behavior of shock waves and jumps.

II. Progress over the last year: During the past year the following investigations have been completed: (i) the dynamics of separated jumps; (ii) time-dependent analysis of deep ocean eddies, and (iii) the ellipticity of anticyclonic eddies. In addition, the following investigations have begun: (i) the flow through the Unimak Pass; and (ii) the movement of isolated anticyclonic eddies in a finite depth ocean (and the formation of Taylor Columns). With the exception of the deep eddies study and the study of the flow through the Unimak Pass, which have recently been added to the program (see Section III), all of the investigations mentioned above were discussed in the original proposal.

The investigations associated with (i) trapping of slope water by cyclonic cold-core rings and (ii) dynamics of rotation jumps in a diverging channel, which were also proposed a year ago (see pages 24-28, 30), have not begun yet and are scheduled for the second contract year (March 1984-March 1985).

III. Deviations from original proposal: With the exception of some minor modifications, there are no plans for any changes in the orginally proposed program. The minor changes are associated with additional projects which were not described in the original proposal but were found to be of considerable interest. These projects are: (i) the behavior of unsteady eddies in the deep ocean and (ii) the interaction of warm-core rings and meridional boundaries. As mentioned in Section II, the former study has already been completed; the latter is presently under a cooperative investigation by the principal investigators and Dr. R. Mied (Naval Research Laboratory). These additional projects do not require additional funds.

IV. Publications: During the past year, the following manuscripts have been submitted.

1) Nof, D. (1984): Oscillatory drift of deep ocean eddies. Submitted to Deep-Sea Res..

2) Nof, D. (1984): Shock waves in currents and outflows. Submitted to J. Phys. Oceanogr..

3) Nof, D. (1984): On the ellipticity of anticyclonic eddies. Submitted to Tellus.

An additional manuscript entitled "The dynamics of rotating jumps with application to the Vema Channel" will be submitted before the end of the present contract year.

Upper Ocean Forecasting

James J. O'Brien

The P.I. uses numerical and analytical techniques to understand upper ocean physics on the meso-to large scales and event-to interannual time scales. In early 1983, Cushman-Roisin studies the numerical-stability properties of the mixed leap-frog, Dufort-Frankel scheme and the establishment of an analytical stability criterion. This work will be published as an article in the J. Comp. Phys., Feb., 1984. Subsequently, the problem of the maintenance of the Subtropical Front and its associated countercurrent was solved by Cushman-Roisin. A two-layer version was presented at WHOI in early August and a three-dimensional version is now submitted to the J. Phys. Ocean.. A stay by Cushman-Roisin at the Department of Mathematics at the University of Arizona in early summer provided useful help from applied mathematicians and allowed the writing of a paper on oceanic mesoscale-eddy parameterization, submitted to Geophys. and Astrophys. Fluid Dyn.. Recent months of the year have been devoted to clarifying the various geostrophic regimes that can exist both with and without vertical stratification and to organizing a two-day conference on "Mesoscale Eddies in the Ocean and Their Mathematical Problems", sponsored by the Office of Naval Research and held at FSU on December 8-9, 1983.

In the Indian Ocean project, Luther and O'Brien have had considerable success. Four versions of the model are now running on FSU;s computer: 1) a model with idealized forcing and geometry; 2) a model with realistic geometry and forced by climatic monthly mean observed winds; 3) a model with realistic geometry forced by the monthly means of the FGGE data; 4) and a model with realistic geometry forced by the real-time FGGE winds. The models have sucessfully duplicated most of the observed features of the Somali Current system and the northern Arabian Sea circulation. One paper has been submitted to Progress in Oceanography on the model results. Various aspects of the model results have been presented at two national meetings and at two international conferences. Dr. Luther is now in the process of converting the models to run on a Cyber 205 super computer, (owned by CDC) which will give considerably increased resolution for the model currents, and will allow a larger portion of the Indian Ocean to be modeled accurately. These models have shown that the currents in the northwest Indian Ocean can be predicted accurately if sufficient wind data are available.

J.J. O'Brien has not completed the textbook on numerical modelling. Chapters 2-7 are revised but the remainder of the book has not been completed. The revised schedule indicates completion in late 1984.

Publications and Presentations

Cushman-Roisin, B., and J.J. O'Brien, 1983: The influence of bottom topography on baroclinic transports. J. Phys. Oceanogr., 13, 1600-1611.

Cushman-Roisin, B., 1983: What maintains the Subtropical Front and its associated countercurrent? WHOI-83-41, 103-105.

Cushman-Roisin, B., J.J. O'Brien and R.L. Smith, 1983: On wind and ocean velocity correlations in a coastal-upwelling system, J. Phys. Oceanogr., 13, 547-550.

Cushman-Roisin, B., and H. Svendsen, 1984: Generation and propagation of internal tides in a still fjord, with assessment of limitations of vertical modes and rays, Coastal Oceanogr., 373-396.

Cushman-Roisin, B., 1984: Analytical linear stability criteria for the leap-frog, Dufort-Frankel method. J. Comp. Phys., to appear in February issue.

Cushman-Roisin, B., 1984: Interactions between mean flow and finite-amplitude mesoscale eddies in a barotropic ocean. Submitted to Geophys. Astrophys. Fluid Dyn..

Cushman-Roisin, B., 1984: On the maintenance of the subtropical front and its associated countercurrent. Submitted to J. Geophys. Res..

Klinck, J.M., B. Cushman-Roisin and J.J. O'Brien, 1984: Considerations of coastally forced flow in a branched fjord, Coastal Oceanogr., 451-473.

Luther, M.E., and J.J. O'Brien, 1983: A model of the seasonal circulation in the Arabian Sea forced by observed winds, submitted to Progress in Oceanogr..

Luther, M.E., and J.J. O'Brien, 1983: A numberical model of the seasonal circulation in the Indian Ocean. Transactions, American Geophysical Union, 64, p. 247. Abstract of presentation at the AGU Spring Meeting, Baltimore, Md., 30 May-3 June 1983.

Luther, M.E., and J.J. O'Brien, 1983: Seasonal response of the Indian Ocean to monsoon wind forcing. IUG XVIII General Assembly, IAPSO Programme and Abstracts, pp. 198-199. Abstract.

Luther, M.E., and J.J. O'Brien, 1983: Modeling of the seasonal circulation in the Arabian Basin. Invited paper presented at the Mabahiss/John Murray International Symposium on Marine Science of the North-West Indian Ocean and adjacent waters, Alexandria, Egypt, 3-7 September 1983.

Luther, M.E., and J.J. O'Brien, 1983: The circulation in the Arabian Sea forced by observed winds. Transactions, American Geophysical Union, 64, p. 733. Abstract of presentation at the AGU Fall Meeting, San Francisco, CA., 5-9 December 1983.

Roed, L.P., and J.J. O'Brien, 1983: A coupled ice-ocean model of upwelling in the marginal ice zone, J. Geophys. Res., 88, 2863-2872.

Coastal Sea Level Forcing Along The U.S. East Coast by Winds and Currents

W. Sturges

In this project I am exploring the effects of offshore circulation on flow near the coast, as well as the effect on sea level as observed at the coast.

The first application was to begin a study of the long-shore slope of sea level from Miami to Norfolk. This reexamination of a "hoary old chestnut" was partly because of new geodetic work that had suggested that sea level should slope up to the north along the coast. After this project was well underway, sea level data had been obtained, etc., new results were obtained by Tom Lee and his co-workers at Miami. Based on a large current-meter array off the coast near 30 N, they found (Lee, et al., 1984, in litt.; personal communication) from direct calculation of the terms in the long-shore momentum equation that the sea level slope was in essential agreement with that estimated from oceanographic data some years ago (Sturges, 1974). That is, they find a pressure gradient such that sea level falls to the north, near the coast.

As a result of Lee's findings, I concluded that further work on this specific part of the project would not be productive, and so turned my attention elsewhere. I have been examining data on the shelf and slope at two locations, to study the effects of offshore flow.

Current-meter data on the slope and shelf near 26 N, off the west Florida shelf, is available as a result of a program funded by MMS. A substantial portion of the kinetic energy found in these records is at periods of 10-20 days. A fundamental question is whether the shelf selectively extracts certain frequencies from a broad frequency range in the background forcing, or whether these energetic fluctuations on the slope and shelf are forced by motions of the current, that happen to be at these periods already.

I have examined the positions of the inshore edge of this current (the Loop Current) to search for evidence of selective forcing in the onshore direction. Positions have been digitized along several latitudes, from the satellite IR maps available at 2- and 5-day intervals. The primary result is that yes, there does indeed happen to be a pronounced plateau in the spectrum of current positions, in the range 10-20 days! The variance-preserving spectra show a noticeable "hump" at periods near 12 days. Furthermore, these fluctuations are coherent in the long-shore direction. Calculations to learn whether these fluctuations are coherent with the observed currents are just beginning.

Publications

Allen, J.S. et al., (incl. Sturges), 1983: Physical Oceanography of continental shelves. Rev. Geoph. and Space Physics, 21, pp 1149-1181.

Cragg, John, G.T. Mitchum and W. Sturges, 1984: Wind-induced sea-surface slopes on the West Florida Shelf. J. Phys. Oceanogr., in press.

Mitchum, Gary T. and W. Sturges, 1982: Wind-Driven Currents on the West Florida Shelf. J. Phys. Oceanogr., 12, pp 1310-1317.

Mitchum, Gary T. and W. Sturges, 1983: On the wind stress - sea level power law. Unpublished Tech. Report, Florida State University, 17 pp.

Sturges, W., 1983: On interpolating gappy records for time-series analysis. J. Geophys. Res., 88, pp 9736-9740.

Sturges, W. and J.C. Evans, 1983: On the variability of the Loop Current in the Gulf of Mexico. J. Mar. Res., 41, pp 639-653.

The Role of Exopolymer Binding in Microfouling And Sediment Erodability

D.C. White and D. Thistle

Our long-term objectives are: a) to describe the community structure of the initial fouling community (IFC) using chemical 'signatures' defined from manipulative experiments and cultures of initial fouling organisms, b) to determine the reproducibility of the IFC with respect to time and surface type and relate this to exopolymer production, c) to develop a test system to quantify differences of adherent and non-adherent microbes under various conditions, and d) to understand the binding of sediment by exopolymers.

We are taking a functional-group approach to the problem of defining the community structure of the IFC, e.g., quantifying the relative abundances of procaryotes vs. eucaryotes, splitting the procaryotes into aerobic, faculative, and anaerobic groups. By relating specific subsets of the IFC to type of surface, time of year, exopolymer concentraton, and facilitation of corrosion of a surface, we hope to define preconditions for the development of a microfouling community and its consequences for a surface. From this year's manipulative experiments, we have established fatty-acid signatures for environmental samples that will allow us to estimate the relative abundance of aerobic, facultative, and anaerobic microbes on a surface. Work on the reproducibility of the IFC has begun on the first test surface (teflon).

We have gathered the instrumentation to build a test system to investigate the chemistry of fouling microbes in the laboratory. The system includes a sterilizable apparatus in which microbial species isolated from the initial fouling community are given the opportunity to adhere to a surface in regions of known fluid shear and a Fourier transform infrared spectrometer (FT-IR) that is able to describe nondestructively the suface chemistry of the microbes in the different shear regions and the changes that occur over time as the fouling film develops. The strength of this approach lies in the ability to do chemical analyses to describe the microbial community after FT-IR analyses thereby identifying the functional groups responsible for the initial chemistry of fouling-film formation.

Our attempts to identify the binding moieties of microbial exopolymers were frustrated by the complexities of carbohydrate chemistry; our simple manipulations have led to complex results. We intend to pursue this issue using mutant strains of a single species to produce exoplymers that differ slightly in composition whose binding strengths can then be compared. We are also initiating laboratory cultures of nematodes so investigation of these potentially important mucus producers can begin.

Publications and Reports

Findlay, R.H. and D.C. White, 1983: Polymeric beta-hydroxyalkanoates from environmental samples and Bacillus megaterium. Appl. Environ. Microbiol. 45: 71-78.

Findlay, R.H., D.J. Moriarty and D.C. White, 1983: Improved method of determining muramic acid from environmental samples. Geomicrobiology J. 3: 133-150.

Gehron, M.J. and D.C. White, 1983: Sensitive measurements of phospholipid glycerol in environmental samples. J. Microbiol. Methods 1: 23-32.

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White, D.C. and P.H. Benson, 1982: Determination of the biomass, physiological status, community structure and extracellular plaque of the microfouling film. U.S. Naval Institute Press.

White, D.C., 1983: Analysis of microorganisms in terms of quantity and activity in natural environments. In Microbes in their natural environemnts, J.H. Slater, R. Whittenbury and J.W.T. Wimpenny (editors). Society for General Microbiology Symposium 34: 37-66.

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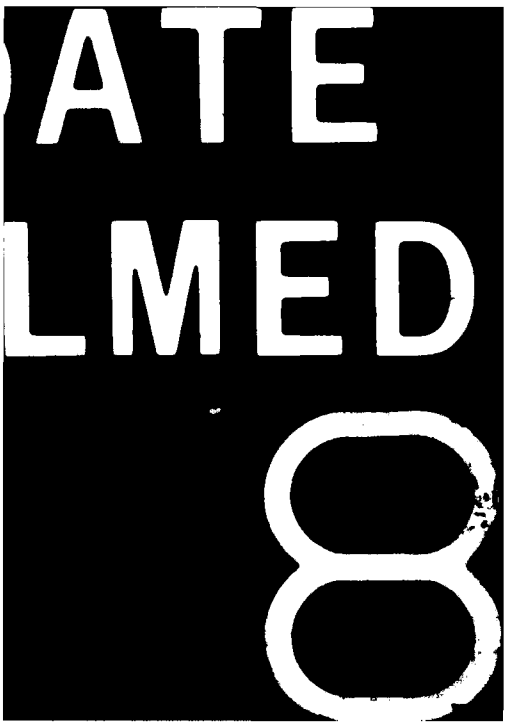
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